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Effect of removing the spring flush and nitrogen and phosphorus fertilization on the late ripening of cactus pear *Opuntia ficus-indica* (L.) Mill

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Abstract

The present work aims to study the effect of removing the spring flush (scozzolatura practice) and nitrogen and phosphorus fertilization on fruit yield and quality of the late fruiting of cactus pear *Opuntia ficus-indica* (L.) Mill. To meet this objective, an experiment was carried out on an adult plantation of ‘Aissa’ cv in the Agadir area. Treatments of fertilization used are: T0 (not fertilized plot: contains only the soil reserve in NP: 40-20 kg N-P ha^{-1}), T1: 226 kg N ha^{-1}, T2: 114 kg P_2O_5 ha^{-1} and T3: 226-114 kg N-P_2O_5 ha^{-1}. The whole spring flush was removed during the full flowering stage (50% flowers in bloom); it was practiced on April 20, 2019. Obtained results showed that removing the spring flush led to a second flush of flowering (reflowering) 46 days after the spring flowering and an off-season late fruiting 68 days after the seasonal fruiting. The scozzolatura practice also has improved the fruit size and taste and its content in sugars, and reduced the number of seeds per fruit. Nitrogenous and phosphor-nitrogenous fertilizations improved the emission of shoots and flowers, fruit yield and size of scozzolatured and not scozzolaturated plants and their effect is more important on scozzolatured plants than on not scoscozzolatured ones. However, phosphorous fertilization alone does not affect these phenological and yield parameters and nitrogen and phosphorus fertilizations have no effect on the organoleptic parameters of the fruits (the rate of juice and sugars and the pH and acidity titratable of the juice).

Keywords: Cactus pear; Scozzolatura practice; Nitrogen and phosphorus fertilization; Fruit yield and quality; Late ripening

1 Introduction

Cactus pear is a species which flowers and usually fructifies only once a year. Flowers are often born on one-year-old cladodes and young shoots are often born on cladodes two years old and older. Flowering occurs in spring and fruit ripening occurs during the summer season [1, 2]. However, cactus pear may flower a second time when climatic conditions are favorable [3] or under advanced cultivation practices such as fertigation and the scozzolatura practice [4, 5]. The scozzolatura practice consists of removing the spring flush (vegetative and floral buds) to induce a second flush of flowers and cladodes 30 to 40 days after the removing of the spring flush [6]. The second flush of flowers leads to an off-season late fruiting with large size fruits, which are tastier, sweeter and with more flesh and fewer seeds than the seasonal fruits [4, 7, 8, 9, 10, 11, 12].

Some authors reported that the increase in fruit yield is attributed to mineral fertilizers, including nitrogen and phosphorus [13, 14, 15, 16, 17]. Other authors showed that phosphor-nitrogenous fertilization improved the emission of flowers, yielded fruits per plant and fruit yield and size in not scozzolaturated plants [10, 18, 19, 20, 21, 22, 23] and scozzolaturated ones [5, 24]. However, some other authors indicated that mineral fertilization does not affect fruit

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quality [16, 25] and potassium fertilization alone does not affect fruit yield [16]. Moreover, phosphor-nitrogenous fertilization does not affect the periods of reflowering and late ripening nor the organoleptic parameters of the fruits (juice and sugars content, pH, titratable acidity, …) [11, 24]. Nerd and Mizrahi [5] showed that application of 120 kg N ha^{-1} after the scozzolatura practice increased the emission of flowers compared to unfertilized plants and application of 225-45 kg N-P_2O_5 ha^{-1} also improved the emission of flowers and fruit yield [11, 24]. Our work aims to study the effect of an application of nitrogen and phosphorus fertilizations independently after the scozzolatura practice on the reflowering and late fruiting of cactus pear.

2 Materials and methods

2.1 The site of trials and plant material used in the study

The trials were carried out in the experimental station of the Hassan II Institute of Agronomy and Veterinary Medicine, Horticultural Complex of Agadir: latitude 30° 22' N, longitude 9° 39 W and altitude 32 m. The mean temperature of the site of trials during the trial period ranges from 15 to 25 °C and the mean temperature of the year is 19 °C. These temperature conditions are favorable for the cultivation of cactus pear [26]. The soil of the parcel of trials has a silty texture with 19.55% coarse sand, 30% fine sand, 20.6% coarse silt, 24.4% fine silt and 5.45% clay. The soil is moderately alkaline with a pH of 8.4 and a mean content of 5.78% active limestone. Studied species is *O. ficus-indica* 'Aissa' cv which is a spineless variety 16 year old. The plants have a mean width of 1.6 m and a mean height of 2 m. Plant spacing is 3 m between rows and 2 m between plants in the row (1666 plants ha^{-1}). Because of the infestation of cactus plantations in Morocco by the carmine cochineal *Dactylopius opuntiae* (Cockerell), the control of this insect required a plant protection management of the parcel of trials by chemical treatments against this specific pest of cactus pear. The chemical product used in the control of this pest is 'Dursban 4' with a concentration of 480 g l^{-1} of the active ingredient Chlorpyriphos-ethyl, which belongs to the chemical family of organophosphate organochlorines. The amount used of this commercial product in the treatments is 150 cc hl^{-1} and the treatments were applied during the following dates: March 6 and 14, April 2, May 5, June 24, July 12 and August 15, 2019.

2.2 Treatments of fertilization used and experimental design adopted

Before the establishment of a fertilization program for cactus pear, the knowledge of the content of mineral elements in the soil is essential in order to establish the amounts of fertilizers to be brought. Chemical analyses of the soil of the parcel of trials showed that the content of nitrogen and phosphorus in the soil is 40 kg N-20 kg P per hectare. The treatments of fertilization used are: T0: (control without input: contains only the soil reserve in NP: 40-20 kg N-P ha^{-1}); T1: (226 kg N ha^{-1}) (186 brought+ 40 kg of the soil reserve); T2: (114 Kg P_2O_5 ha^{-1}) (94 brought + 20 kg of the soil reserve); T3: (226-114 Kg N-P_2O_5 ha^{-1}) (186-94 brought + 40-20 kg of the soil reserve). Plants are watered 4 times with an amount of 10 mm per watering and seven days interval between watering. The first watering is applied just after the scozzolatura practice.

Table 1 Amounts of nitrogen and phosphorus used per supply and amounts of fertilizers supplied per plant and dates of the supplies on an adult plantation of cactus pear *O. ficus-indica* Aissa cv in the Agadir region

Fertilizers supplied	Date of supply of the fertilizers					
	April 25 2019			May 10 2019		
	Treatment of fertilisation used					
	T1 (226 kg N ha^{-1})	T2 (114 kg P_2O_5 ha^{-1})	T3 (226 kg N-114 kg P_2O_5 ha^{-1})	T1	T2	T3
Amount of P_2O_5 supplied per plant (g)	--	67,22	67,22	--	--	--
Amount of Ammonium nitrate supplied per plant (g)	240,81	--	150,34	160,54	--	160,54
Amount of MAP supplied per plant (g)	--	--	25-2,53	--	--	--
Amount of super phosphate triple supplied per plant (g)	--	334,84	--	--	--	--

The fertilizers are brought with the irrigation watering, the amount of nitrogen brought are divided into two inputs (60% with the first watering and 40% with the second watering) and the amounts of phosphorus applied are provided in a single supply with the first watering (Table 1).

We have two factors to study: nitrogen and phosphorus fertilization and the scozzolatura practice. The experimental design used is a complete randomized block design with 3 blocks and 8 treatments randomly distributed in the blocks and each treatment is composed of a treatment of fertilization and a treatment of scozzolatura. An experimental unit is composed of two plants. The scozzolatura practice consist of removing the whole spring flush of flowers, and cladodes during the full flowering stage (50% flowers in bloom); it is performed on April 20, 2019.

2.3 Measures and observations realized

2.3.1 The monitoring of flowering, shoot emission and fruit ripening

The cultivation cycle of cactus pear in the site of trials extends from March (the start of the flowering period) to September (the end of the ripening period of scozzolaturated plants). Observations began in March 2019 on all the plants of the treatments of fertilization and scozzolatura practice. The monitoring of flowering and shoot emission consists in counting the number of flowers and shoots per plant before and after the treatments of fertilization and scozzolatura practice. It is carried out twice a week during the whole cultivation cycle on a sample of 20 cladodes per plant (10 one-year-old cladodes and 10 of two years) that are randomly selected from the four orientations of the plant. The monitoring of fruit ripening began just after fruit set on all the treatments of fertilization and scozzolatura practice. It is carried out once a week on the same sample of cladodes used for the monitoring of flowering and shoot emission, by counting the number of ripened fruits (change in color of the fruit peel from green to yellowish green) in relation to total number of fruits in the plant. The percentage of ripened fruits is determined according to Oelofse *et al.* [27]:

$$\%\, ripened\ fruits = \frac{\text{Number of ripened fruits}}{\text{Total number of fruits in the plant}} \times 100$$

The flowering and fruit ripening periods are determined according to Chessa and Nieddu [28]. The period of flowering or fruit ripening extends from the beginning of flowering (5% flowers in bloom) or fruit ripening (5% ripened fruits) to the end of flowering (100% flowers in bloom) or fruit ripening (100% ripened fruits). The date of full flowering corresponds to 50% flowers in bloom and that of full ripening corresponds to 50% ripened fruits.

2.3.2 Study on fruit quality at the ripening stage

To study the fruit quality at ripening stage, a sample of 20 ripened fruits (5 fruits on each orientation) was randomly selected on each treatment of fertilization and scozzolatura practice. Parameters studied are: fruit, pulp and skin fresh mass, fruit dimensions (fruit length and diameter), the skin thickness, the number of seeds per fruit and the organoleptic parameters of the fruits (the content of juice and sugars in the fruit and the pH and titratable acidity of the juice). Fruit, pulp and skin fresh mass are measured with an electric balance with a precision of 0.01 g. Fruit dimensions and peel thickness are measured using a caliper. The number of seeds per fruit is determined on a piece of 10 g pulp, the content of sugars in the fruit or degree Brix is determined using a refractometer and the content of juice in the fruit is determined according to the following formula:

$$\%\, juice = \frac{Juice\ mass}{Fruit\ pulp\ mass} \times 100$$

The pH of the juice is determined with a pH meter and the titratable acidity of the juice is also determined using a pH meter by diluting 10 g juice into 10 ml distilled water and then titrating the juice solution with NaOH 0,1 N, using phenolphthalein as a colored indicator until the juice turns to pink color. One ml NaOH 0.1 N neutralizes 0.64 g citric acid. The titratable acidity of the juice is determined according to Paul *et al.* [29]; it is expressed in g of citric acid per liter of juice.

$$\text{AAC} = 0.64 \times \text{V(NaOH)}$$

AAC: Amount of acids or titratable acidity of the juice: expressed in g citric acid per liter of juice.

V(NaOH): volume NaOH 0.1 N used in the titration (in ml).

2.4 Statistical analysis of data

Statistical analysis of data was carried out with MINITAB software. It focused on the analysis of variance with two parameters, and data analysis was also completed with a comparison of means using Tukey test.

3 Results and discussion

3.1 Effect of removing the spring flush and nitrogen and phosphorus fertilization on the reflowering and the emission of shoots and flowers

3.1.1 Effect on the reflowering

Nitrogen and phosphorus fertilization does not affect ($p > 0.05$) the flowering period of scozzolatured and not scozzolatured plants of cactus pear, while the scozzolatura practice affect significantly ($p \leq 0.001$) the reflowering of the plants (Figure 1). The flowering period of scozzolatured and not scozzolatured plants and the number of days that are required to reach a flowering stage from the beginning of flowering are presented in Table 2. The start date of flowering (5% flowers in bloom): March 26 2019 may be considered as zero day. The scozzolatura practice delayed the reflowering of scozzolatured plants by 41 days compared to not scozzolatured plants (Table 2). These results are consistent with those of several authors who reported that the scozzolatura practice induces a second flush of flowering 30 to 40 days after this practice [5, 7, 8, 12, 24, 30].

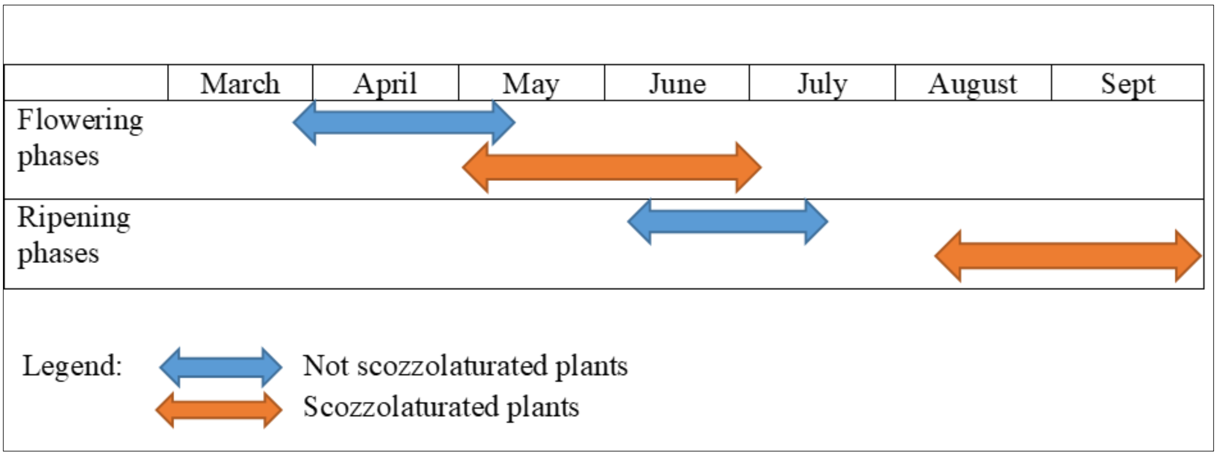

Figure 1 The flowering and ripening phases of scozzolaturated and not scozzolaturated plants of cactus pear *O. ficus-indica* Aissa cv in the Agadir region, Morocco

Table 2 Dates of flowering and ripening stages of scozzolaturated and not scozzolaturated plants and number of days required to reach a flowering or a ripening stage of cactus pear *O. ficus-indica* Aissa cv in the Agadir region

		Not scozzolaturated plants	**Scozzolaturated plants**	**Not scozzolaturated plants**	**Scozzolaturated plants**
		Date of the flowering stage		**Date of the ripening stage**	
Flowering or ripening stage	Start date of flowering or ripening (5% flowers in bloom or ripened fruits)	March 26 2019	May 05 2019	June 07 2019	August 12 2019
	Full blooming or ripening stage (50%	April 20 2019	June 05 2019	June 28 2019	September 04 2019

	flowers in bloom or ripened fruits)				
	End of flowering or ripening (100% flowers in bloom or ripened fruits)	May 14 2019	July 02 2019	July 17 2019	September 30 2019
		Number of days required to reach a flowering or ripening stage		Number of days between scozzolaturated and not scozzolaturated plants	
Flowering stages	Start date of flowering	0	50	45	
	Full blooming stage	25	71	41	
	End flowering stage	49	98	44	
Ripening stages	Start date of ripening	0	66	60	
	Full ripening stage	21	89	62	
	End ripening stage	40	115	70	

3.1.2 *Effect on the emission of shoots and flowers*

The scozzolatura practice and nitrogen and phosphorus fertilization affect significantly ($p \leq 0.001$) the emission of shoots and flowers in cactus pear. For all the treatments of fertilization, the number of flowers emitted by scozzolatured plants is lower than the number of flowers emitted by not sscozzolatured plants (Table 3). For scozzolatured and not scozzolatured plants, the phosphor-nitrogenous fertilization treatment (T3) gave the highest number of flowers per plant, it is followed by the nitrogen fertilization treatment (T1) and the phosphorus fertilization treatment (T2) and the unfertilized control (T0) are the latest (Table 3).

Table 3 Effect of the scozzolatura practice and nitrogen and phosphorus fertilization on the emission of shoots and flowers, yielded fruits and fruit yield of cactus pear *O. ficus-indica* Aissa cv in the Agadir region

Treatment of scozzolatura	**Treatment of fertilization**				**Treatment of fertilization**			
	T0	**T1**	**T2**	**T3**	**T0**	**T1**	**T2**	**T3**
	Number of flowers emitted per plant				**Number of shoots emitted per plant**			
Not scozzolaturated plants	189 c	230 a	192 c	237 a	61 c	141 b	62 c	143 b
Scozzolaturated plants	90 d	168 b	93 d	171 b	32 d	181 a	34 d	181 b
	Number of yielded fruits per plant				Fruit yield (kg per plant)			
Not scozzolaturated plants	179 b	223 a	183 b	230 a	16.49 e	27.13 b	16.93 e	30.80 a
Scozzolaturated plants	83 d	163 c	87 d	166 c	10.15 e	22.70 d	10.60 f	24.63 c

a, b, c and d: Comparison groups according to Tukey test (Confidence level: 95%)

The interaction of the two factors the scozzolatura practice and NP fertilization affect significantly ($p \leq 0.05$) the number of flowers emitted per plant. Not scozzolaturated plants fertilized with T3 treatment (phosphor-nitrogenous fertilization) gave the highest number of flowers per plant (237 flowers) and scozzolaturated and unfertilized plants gave the lowest number of flowers per plant (90 flowers) (Table 3). The effect of nitrogen and phosphor-nitrogenous fertilization on the emission of flowers is more beneficial in scozzolatured plants than in not scozzolatured plants. In scozzolatured plants, these treatments of fertilization increased the number of flowers emitted per plant by 81 flowers compared to the control (T0) and T2 treatment of phosphorus fertilization. However, in not scozzolaturated plants, nitrogen and phosphor-nitrogenous fertilizations increased the number of flowers emitted per plant by only 48 flowers compared to T0 and T2 (Table 3).

The scozzolatura practice does not affect significantly ($p > 0.05$) the emission of shoots, while nitrogen and phosphorus fertilization affect significantly ($p \leq 0.001$) the emission of shhots (Table 3). Nitrogen and phosphor-nitrogenous fertilizations yielded a number of shoots per plant (it is almost similar: 162 and 161 respectively) which is higher than that of phosphorus fertilization and the control (49 and 46 shoots per plant respectively) (Table 3). Interaction of the two factors the scozzolatura practice and NP fertilization affect significantly ($p \leq 0.001$) the emission of shoots. The best interaction is obtained with scozzolaturated and fertilized plants with N and N-P (181 shoots per plant) and the lowest interaction (32 shoots per plant) is obtained with scozzolaturated and unfertilized plants (Table 3). Our results are consistent with those of several authors who reported that mineral fertilization affect the emission of shoots and flowers and that the effect of nitrogen and phosphorus is greater than that of the other elements. Moreover, the application of a high amount of nitrogen fertilization on scozzolatured plants affect significantly the emission of shoots and flowers [16, 20, 24, 32, 33].

3.2 Effect of the scozzolatura practice and NP fertilization on fruit yield and late ripening of cactus pear

3.2.1 Effect on the late ripening

The dates of the ripening stages of scozzolaturated and not scozzolaturated plants of cactus pear and the number of days required to reach a ripening stage from the start date of the ripening phase, which is considered as day zero, are presented in Table 2. The scozzolatura practice affect significantly ($p \leq 0.001$) the late ripening of cactus pear, while NP fertilization does not affect significantly ($p > 0.05$) the late ripening of this species. The scozzolatura practice has delayed fruit ripening for 62 days compared to not scozzolaturated plants (Figure 1). Our results are in agreement with those of several authors who indicated that the scozzolatura practice leads to an off-season late fruiting, which is generally ripened, between September and December [4, 5, 8, 12, 24]. Moreover, when temperatures are low during the late autumn and the winter season, fruits issued from the scozzolatura practice do not ripen until the spring of the following year [3].

3.2.2 Effect on yielded fruits per plant

The scozzolatura practice, NP fertilization and the interaction of the two factors affect significantly ($p \leq 0.05$) the number of yielded fruits per plant (Table 3). For all the treatments of fertilization, not scozzolaturated plants yielded a higher number of fruits than scozzolaturated plants (Table 3). For scozzolaturated and not scozzolaturated plants, the phosphor-nitrogenous fertilization treatment (T3) gave the highest number of fruits per plant, it is followed by the nitrogen fertilization treatment (T1), the phosphorus fertilization treatment (T2) comes next and the unfertilized control (To) is the latest (Table 3). The best interaction is obtained with not scozzolaturated plants and T3 treatment of fertilization (230 yielded fruits per plant) and the lowest interaction is obtained with scozzolatured and unfertilized plants (83 yielded fruits per plant) (Table 3). Our results are similar to those of several authors who reported that mineral fertilization, including nitrogen and phosphor-nitrogenous fertilization, affect the production of fruits in scozzolaturated and not scozzolaturated plants of cactus pear [10, 16, 22, 23, 24].

3.2.3 Effect on fruit yield

The scozzolatura practice, NP fertilization and the interaction of the two factors affect significantly ($p \leq 0.05$) fruit yield of cactus pear. For all the treatments of fertilization, not scozzolaturated plants yielded more than scozzolaturated plants (Table 3). For scozzolaturated and not scozzolaturated plants, phosphor-nitrogenous fertilization treatment yielded more than other fertilization treatments, it is followed by nitrogen fertilization treatment (T1) and phosphorus fertilization treatment (T2) and the control are the latest with an almost similar yield (Table 3). The best interaction is obtained with not scozzolaturated and fertilized plants with T3 (30.80 kg per plant) and the lowest interaction is obtained with scozzolatured and unfertilized plants (10.15 kg per plant) (Table 3). Our results are consistent with those of several authors who reported that mineral fertilization increased fruit yield in cactus pear [10, 11, 14, 15, 16, 22, 23].

3.3 Effect of the scozzolatura practice and NP fertilization on fruit quality

3.3.1 Effect on fruit size (fruit mass and dimensions) and skin thickness

The scozzolatura practice, NP fertilization and the interaction of the two factors affect significantly ($p \leq 0.001$) the fresh mass of the fruit, pulp and skin (Table 4). For all the treatments of fertilization, the fresh mass of the fruit, pulp and skin of scozzolaturated plants is higher than that of the fruit, pulp and skin of not scozzolaturated plants (Table 4). For scozzolaturated and not scozzolaturated plants, phosphor-nitrogenous fertilization treatment (T3) yielded fruits with a mean fresh mass of the fruit, pulp and peel that are higher than that of the fruits yielded by the other treatments of fertilization. It is followed by nitrogen fertilization treatment (T1) and phosphorus fertilization treatment (T2) and the unfertilized control (T0) are the latest with almost similar values for these parameters (Table 04). Phosphor-nitrogenous fertilization increased the fruit fresh mass compared to nitrogen or phosphorus fertilization alone. The best interaction is obtained with scozzolaturated and fertilized plants with T3 (169 g, 99.85 and 68.91 respectively for the mean fresh mass of the fruit, pulp and peel) (Table 4).

Table 4 Effect of the scozzolatura practice and NP fertilization on fruit size (fruit mass and dimensions) and peel thickness of cactus pear *O. ficus-indica* Aissa cv in the Agadir, region

Treatment of scozzolatura	Treatment of fertilization				Treatment of fertilization			
	T0	T1	T2	T3	T0	T1	T2	T3
	Fruit fresh mass (g)				Pulp fresh mass (g)			
Not scozzolaturated plants	91.67 f	139 d	92.33 f	150 c	54.09 f	80.18 d	54.46 f	88.44 c
Scozzolaturated plants	126 e	159.67 b	127.67 e	169 a	73.50 e	91.21 b	74.49 e	99.58 a
	Peel fresh mass (g)				Peel thickness (mm)			
Not scozzolaturated plants	35.83 f	51.82 d	34.83 f	57.03 c	4.10	4.58	4.12	4.74
Scozzolaturated plants	49.14 e	61.27 b	49.79 e	68.91 a	4.90	5.24	4.91	5.37
	Fruit length (cm)				Fruit diameter (cm)			
Not scozzolaturated plants	6.21	7.25	6.15	7.86	4.71	5.54	4.77	5.96
Scozzolaturated plants	7.15	8.12	7.23	8.34	5.34	6.12	5.31	6.51

a, b, c, d, e and f: comparison groups according to Tukey test (Confidence level: 95%)

The scozzolatura practice and NP fertilization also affect significantly ($p \leq 0.001$) the peel thickness and fruit dimensions (fruit length and diameter), but the interaction of the two factors does not affect significantly ($p > 0.05$) these parameters. For all the treatments of fertilization, fruit dimensions and skin thickness are higher in the fruits of scozzolaturated plants than in the fruits of not scozzolaturated plants (Table 4). For scozzolaturated and not scozzolaturated plants, the phosphor-nitrogenous fertilization treatment (T3) yielded fruits with dimensions and peel thickness that are higher than in the fruits of the other treatments of fertilization. It is followed by nitrogen fertilization treatment (T2) and the phosphorius fertilization treatment (T2) and the control (T0) are the latest with almost similar values for these parameters (Table 4). Our results are consistent with those of several authors who reported that appropriate phosphor-nitrogenous fertilization improves fruit size and increase skin thickness of scozzolaturated plants [11] and not scozzolaturated ones [10, 22, 23]. Moreover, the off-season late fruits of scozzolatured plants are larger than the seasonal fruits [4, 7, 8, 9, 11, 12]. Fruit size of scozzolaturated plants (a mean fruit mass of 120 g) and the skin thickness of scozzolaturated and not scozzolaturated plants and of all the treatments of fertilization (less than 6 mm) meet the marketing criterion of cactus pear fruits in south Africa [19, 34, 35].

3.3.2 Effect on the organoleptic parameters of the fruits

With the exception for the content of juice in the fruit, the scozzolatura practice affect significantly ($p \leq 0.05$ or 0.001) the other organoleptic parameters of the fruit (the content of sugars in the fruit, the pH and titratable acidity of the juice and the number of seeds per fruit) (Table 5). The content of sugars in the fruit and the pH of juice are higher in scozzolaturated plants (15.62 °Brix and pH of 6.44) than in not scozzolaturated plants (14.17 °Brix and pH of 6.37). While the titratable acidity of the juice of scozzolatured plants is slightly lower (0.67 g l^{-1}) than that of not scozzolaturated plants (0.72 g l^{-1}) (Table 5). Data on the organoleptic parameters of the fruits in relation to NP fertilization are not presented here because NP fertilization does not affect significantly ($p > 0.05$) these parameters.

Our results are consistent with those of several authors who reported that the fruits of scozzolaturated plants are tastier, sweeter and with less seeds than the seasonal fruits of not scozzolaturated plants [4, 8, 11, 12]. While nitrogen and phosphorus fertilization does not affect the organoleptic parameters of the fruits of scozzolatured plants [11] and not scozzolaturated ones [22, 23]. However, Ahmed *et al.* [10] indicated that N-P-K mineral fertilization improves the organoleptic parameters of the fruits of not scozzolaturated plants (the content of juice and sugars in the fruit and the pH and titratable acidity of the juice). Likely because the young plantation they studied (5 years old) responds well to mineral fertilization than the old plantation (more than 14 years old) studied by Arba [22] and Arba *et al.* [23].

Table 5 Effect of the scozzolatura practice and NP fertilization on the fruit organoleptic parameters of cactus pear *O. ficus-indica* Aissa cv in the Agadir region

The organoleptic parameters of the fruits	Not scozzolaturated plants	Scozzolaturated plants	
The content of juice in the fruits (%)	60.71	61.41	ns
The content of sugars in the fruits (°Brix)	14.17	15.62	**
Titratable acidity of the juice (g l^{-1})	0.72	0.67	**
pH of the juice	6.37	6.44	*
Number of seeds per 10 g pulp	40.25	38.08	*

ns: no significant difference; *: significant difference at $p \leq 0.05$; **: significant difference at $p \leq 0.001$.

4 Conclusion

The scozzolatura practice made it possible to obtain a second flush of flowers or reflowring, which gave an off-season late ripening with large size fruits that are tastier, sweeter and with less seeds than the seasonal fruits. However, NP fertilization does not affect the periods of reflowering and late ripening and the organoleptic parameters of the fruits. Nitrogen and phosphor-nitrogenous fertilizations improved the emission of shoots and flowers and fruit yield and size of scozzolaturated and not scozzolaturated plants and the effect of these fertilizations is more beneficial on scozzolaturated plants than on not scozzolaturated ones. However, phosphorus fertilization alone does not affect these physico-chemical parameters of the fruit. The scozzolatura practice, nitrogen, and phosphor-nitrogenous fertilizations play an economic importance for farmers by allowing them to sell high quality off-season fruits with attractive prices on the local market. Fruit yield of scozzolaturated and fertilized plants with nitrogen (41 tons ha^{-1}) led to an increase of 32.50 tons ha^{-1} (382%) compared to a traditional plantation with a mean fruit yield of 8.50 tons ha^{-1}.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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